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(54) **Microfabrication**

(57) A method (Figure 3) for producing microchannel devices, micro-optic components, or the like. A preform (11) is formed as a composite of etch-distinguishable materials (1, 5, 9 and 3, 7) which in cross section have the geometric form, albeit of much enlarged scale, of the end product. A rod-or-fibre is then drawn from this to the desired scale and is sectioned. Surplus material is removed by etching using a selective etchant. Voids formed by etching may then be infilled by material of different optical density, or the exposed internal walls may be metallised.

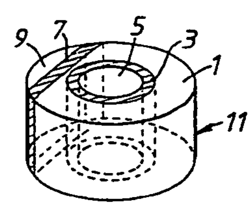

FIG. 3.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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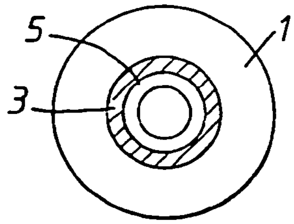

FIG. 1.

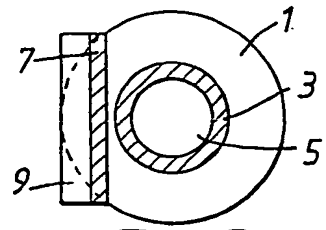

FIG. 2.

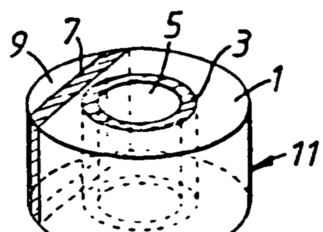

FIG. 3.

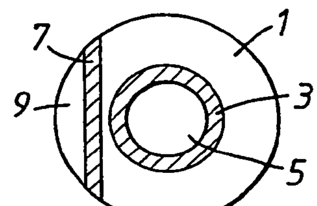

FIG. 4.

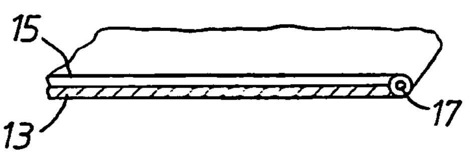

FIG. 5.

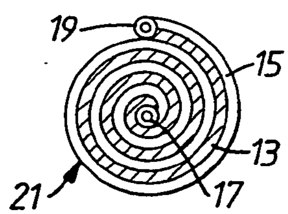

FIG. 6.

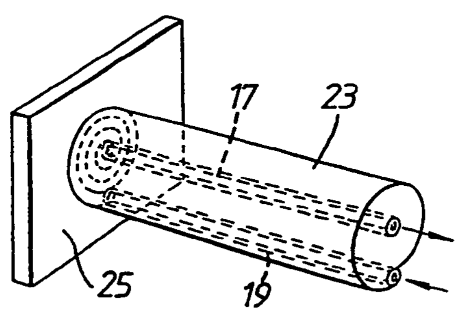

FIG. 7.

SPECIFICATION

Microfabrication

Technical field

The present invention concerns microfabrication methods, more particularly methods for manufacturing micro-channel devices, micro-optic components and like miniature devices.

For optical applications there is currently a requirement for components incorporating very small, tightly configured waveguide structures. These components would have use in signal separators, resonators and the like. Tight configuration is desired to achieve effective and wide separation of fundamental and secondary modes. Also small size is desired so that such components can be integrated with other miniature optical components.

In other applications, for example in gas chromatography, and in biosensors, there is also requirement for tightly configured channel structures.

Background art

Ring resonators and other micro-optic circuit components have been attempted in many technologies, although in most of these technologies tightly bent structures have proved difficult to achieve.

For example, resonators can be made large, but this causes the spurious secondary modes to be of only slightly different frequency and uses substantial physical space. Such large structures can also show hard-to-control dependence of properties on polarization, are generally almost impossible to make reproducibly, and, often exhibit high loss.

These problems arise from a number of causes, principally:-

i) Irregularity of curves. Fabrication of waveguides is made hard by irregularities in the masks or writing used, and in the resists. The usual remedy to this problem involves diffusion, but this sets a practical lower limit upon the radius of curvature that can be produced reliably, because the achievable optical differences are limited.

ii) Refractive Index difference. The use of highly dissimilar materials has caused fabrication problems. Incorporation of metals has proved especially difficult.

iii) Poor reproducibility. The reproducibility of fabrication is often insufficient to give repeatable optical characteristics, the more so where the requirements are particularly stringent for short optical wavelength applications.

Disclosure of the invention

The present invention is provided as a solution to the problems of fabrication just outlined.

In accordance with the invention thus there is provided a method of microfabrication, this method comprising the following steps:-

making a preform of composite materials, materials that are etch distinguishable and configured to have a cross-section of structures geometry, an enlarged scale version of the target component; drawing a rod-or-fibre from this preform, to reduce the scale so that desired in the target component;

sectioning the rod-or-fibre to provide a plurality of like sections; and,

exposing an end face of each section thus to a selective etchant thereby to remove surplus material and thus to define an etched void structure therein.

This method may by supplemented by a further step in which each etched face is fused or bonded to a corresponding cover plate. In this manner it is possible to construct a microchannel device.

Alternatively, the etched voids may be coated or filled. For example, they may be filled with a material of different optical density or they may be coated with a metal. In this manner it is possible to construct micro-optic components, for example ring resonators and the like.

The preform considered above may be entirely solid, or may include void regions that extend along the length thereof.

Brief introduction of the drawings

In the drawings accompanying this specification:-

Figures 1 and *2* are cross-sections showing consecutive stages in the manufacture of a preform;

Figure 3 in a perspective view of the preform produced following the stages shown in the preceding figures;

Figure 4 is a plan view of a ring-resonator, a micro-optic component drawn from the preform shown in the preceding Figure;

Figures 5 and *6* are cross-sections showing consecutive stages in the manufacture of an alternative preform; and,

Figure 7 is a perspective view of a micro-channel device, a device made using the preform of the preceding Figure.

Description of preferred embodiments

In order that this invention might be better understood, embodiments thereof will now be described and reference will be made to the drawings aforesaid. The description that follows is given by way of example only.

Stages in the manufacture of a ring resonator micro-optic component are shown in Figures 1 to 4. The initial stage of manufacture is similar to that adopted in the production of optical fibres. Layers of glass 1 and doped glass material 3 are deposited upon the surface of a rotating hollow cylindrical tube 5 (Figure 1). This tube 5 is then caused to collapse or alternatively is shrunk onto a core rod. Following this stage the side of the rod structure formed is ground flat to within appropriate spacing from the annular cross-section region 3 of doped glass material. Plates of doped glass 7 and undoped glass 9 are then fused to this structure (Figure 2) and machined to the shape of the desired preform 11 (Figure 3). The regions 3 and 7 have thus the form of a concentric axially extending annulus 3 and an axially extending stripe 7. These regions 3, 7 extend the full length of the preform 11.

Out of this preform 11, a fibre is drawn. The

diameter of this fibre is determined by appropriate choice of preform feed and fibre drawing rates and is such that the features scale to that desired in the end product. Typically, the preform will have a diameter on the order of 10^{-2}m and the fibre a diameter on the order of 10^{-5}m, approximately. The feed and drawing rates thus will be in the ratio $1:10^6$ approximately.

The fibre is then sectioned to provide a large number of identical slices (Figure 4). This may be performed by cleaving, tensioning and polishing. The thin slices are then mounted upon and loaded to a supporting carrier. These then are immersed in a bath of a selective etchant solution and the regions of doped glass material removed. In this example the glass material 1, 5, 9 is silica glass and the doped glass material is phosphorus doped silica 3, 7 ($SiO+2 + 5wt\%P_20_5$). It is found that hydrofluoric acid etchant (HF) is satisfactory for this purpose and preferentially etches the doped silica 3, 7. The etched voids can then be exposed to a metal evaporation source and the void walls coated to provide waveguide metallisation. Alternatively, the voids may be infilled with a material of a different optical density for example the optically more dense material arsenic sulphide (As_2S_3) - to produce the final optical component, a ring resonator.

Although the preform considered above is of overall circular cross-section, it will be understood that preforms of other overall cross-section are not precluded and are considered within the general scope of the method above defined.

Stages in the manufacture of a microchannel device are shown in Figures 5 to 7. In the initial stage of manufacture, two sheets 13 and 15 of different glass materials are fused together (Figure 5) and rolled around a length of glass tubing 17. A further length of glass tubing 19 is added at the periphery of this structure. The preform 21 thus has the cross-section formed of two concentric spirals (Figure 6). As above, a rod or fibre is then drawn from this preform 21, and, is sectioned into lengths 23. Each length then is exposed to an etchant to remove surplus glass material 13 from an end face of the section. A continuous channel is thus defined between tubular sections 17 and 19. Construction is completed by bonding or fusing the end face of the section 23 to a glass cover plate 25 (Figure 7).

CLAIMS

1. A method of microfabrication, this method comprising the following steps:-
making a preform of composite materials, materials that are etch distinguishable and configured to have a cross-section of structures geometry, an enlarged scale version of the target component; drawing a rod-or-fibre from this preform, to reduce the scale to that desired in the target component;
sectioning the rod-or-fibre to provide a plurality of like sections; and,
exposing an end face of each section thus to a selective etchant thereby to remove surplus material and thus to define an etched void structure therein.

2. A method, as claimed in claim 1, wherein the preform is a composite of silica glass and phosphorus doped silica glass materials.

3. A method, as claimed in claim 2, wherein the selective etchant is hydrofluoric acid.

4. A method, as claimed in any one of the preceding claims, wherein the preform includes both annular and stripe regions.

5. A method, as claimed in any one of the preceding claims, wherein the drawn rod-or-fibre is sectioned to form a plurality of these slices, surplus material throughout is removed by the etching, and the side walls of the void regions left are coated with metal.

6. A method as claimed in any one of the preceding claims 1 to 4, wherein the drawn rod-or-fibre is sectioned to form a plurality of thin slices, surplus material throughout is removed by the etching and the void regions left are infilled with a material of a different optical density.

7. A method as claimed in claim 6, wherein the voids are infilled with arsenic sulphide.

8. A method as claimed in any of the preceding claims 1 to 3 wherein the preform includes concentric spiral regions that extend between hollow tubular regions at the centre and at the periphery thereof.

9. A method, as claimed in claim 8, wherein the drawn rod-or-fibre is sectioned into lengths, and surplus material, in the immediate vicinity of an end face of each length, is removed by the etching, to provide a continuous channel between the hollow tubular regions.

10. A method of microfabrication when performed substantially as described hereinbefore with reference to and as shown in Figures 1 to 4 or 5 to 7 of the accompanying drawings.

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